Computer Networks

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Signal Encoding Schemes

The process of converting the data or a given sequence of characters, symbols, alphabets etc., into a specified format, so that it can be transmitted.

Encoding Techniques

- Digital data, digital signal
- Analog data, digital signal

Encoding

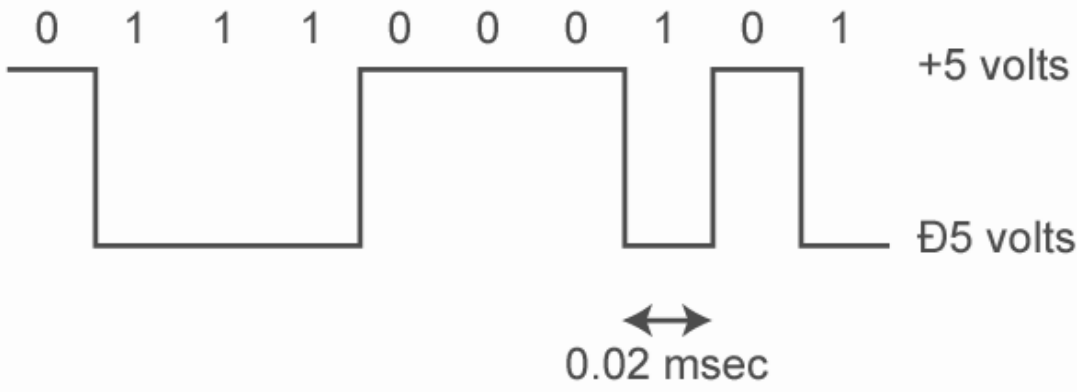
- Digital data, analog signal
- Analog data, analog signal

Modulation

Digital Data - Digital Signal

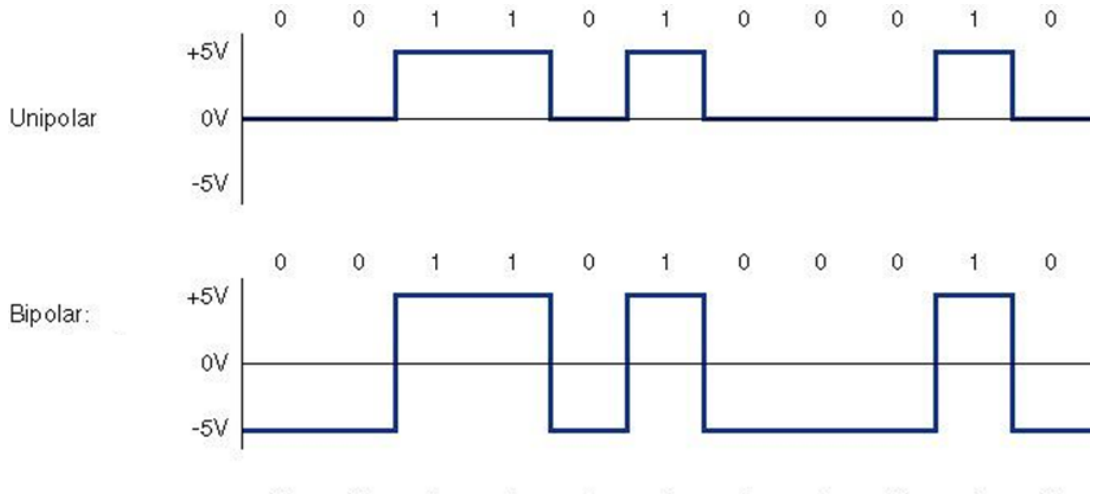
Digital Data, Digital Signal

- Digital signal
  - —Discrete, discontinuous voltage pulses
  - —Each pulse is a signal element
  - —Data encoded into signal elements



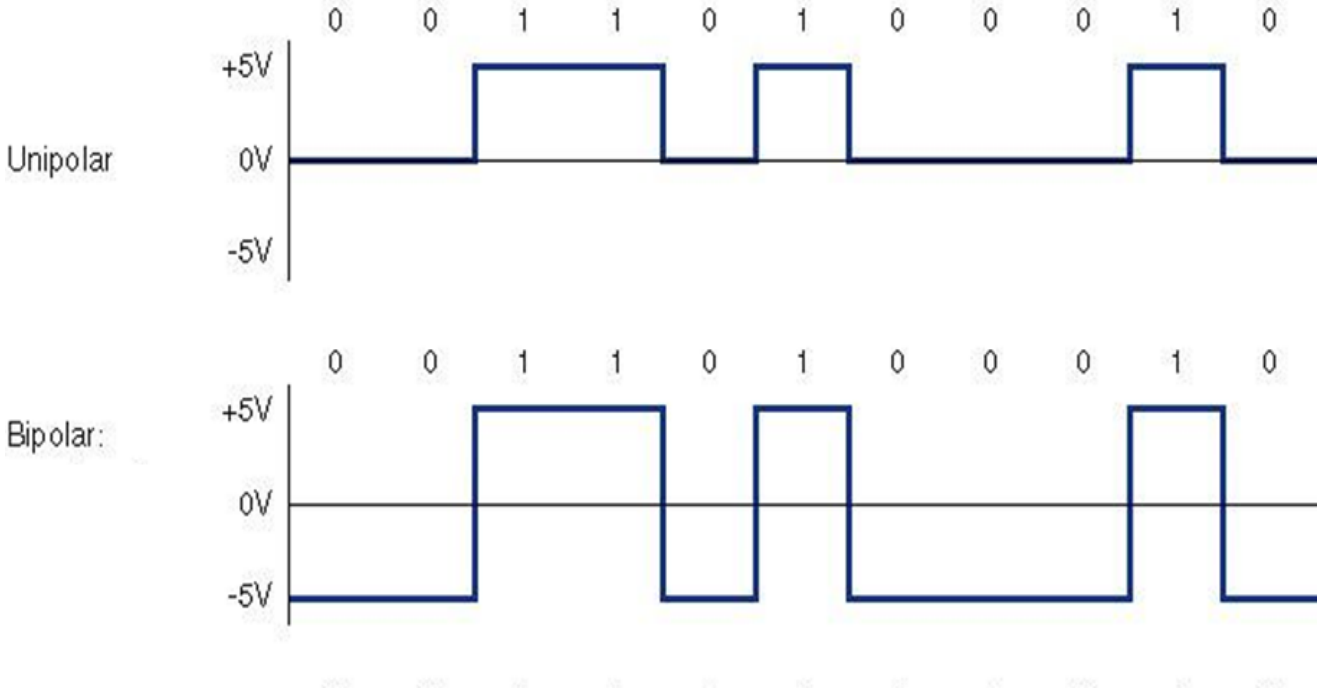
Digital Signals Representation

- With **unipolar** signaling techniques, the voltage is always positive or zero.
- In **bipolar** signaling, the 1's and 0's vary from a plus voltage to a minus voltage.



Digital Signals Representation

- Important
  - Timing of bits - when they start and end
  - Signal levels

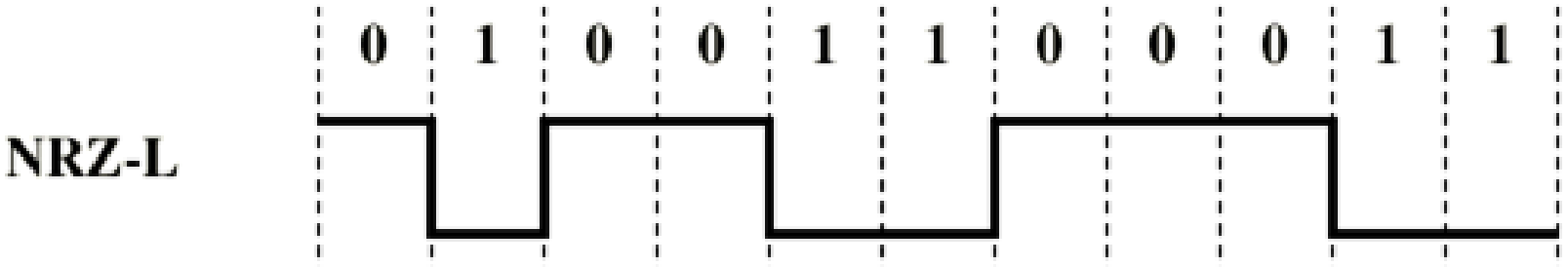


Encoding Schemes

- Nonreturn to Zero-Level (NRZ-L)
- Nonreturn to Zero Inverted (NRZI)
- Manchester
- Differential Manchester

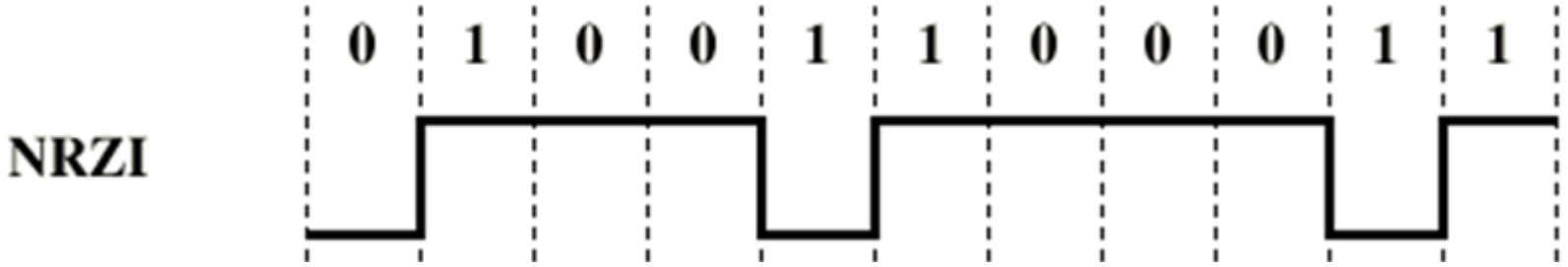
Nonreturn to Zero-Level (NRZ-L)

- Two different voltages for 0 and 1 bits
- Voltage constant during bit interval
  - —no transition i.e. no return to zero level
  - —1 forces a high level or low level
  - —0 forces the other level

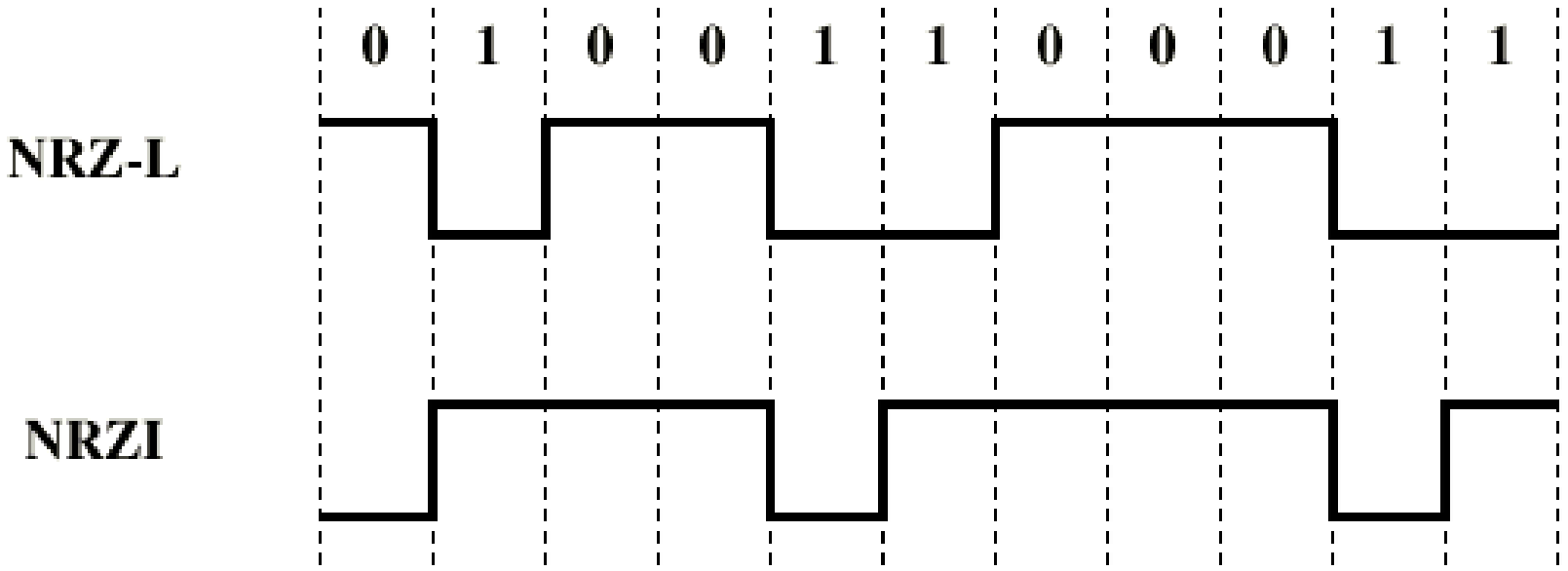


Nonreturn to Zero Inverted

- Constant voltage pulse for duration of bit
- Data encoded as presence or absence of signal transition at beginning of bit time
- Transition (low to high or high to low) denotes a binary 1
- No transition denotes binary 0
  - —1 forces a transition
  - —0 does nothing



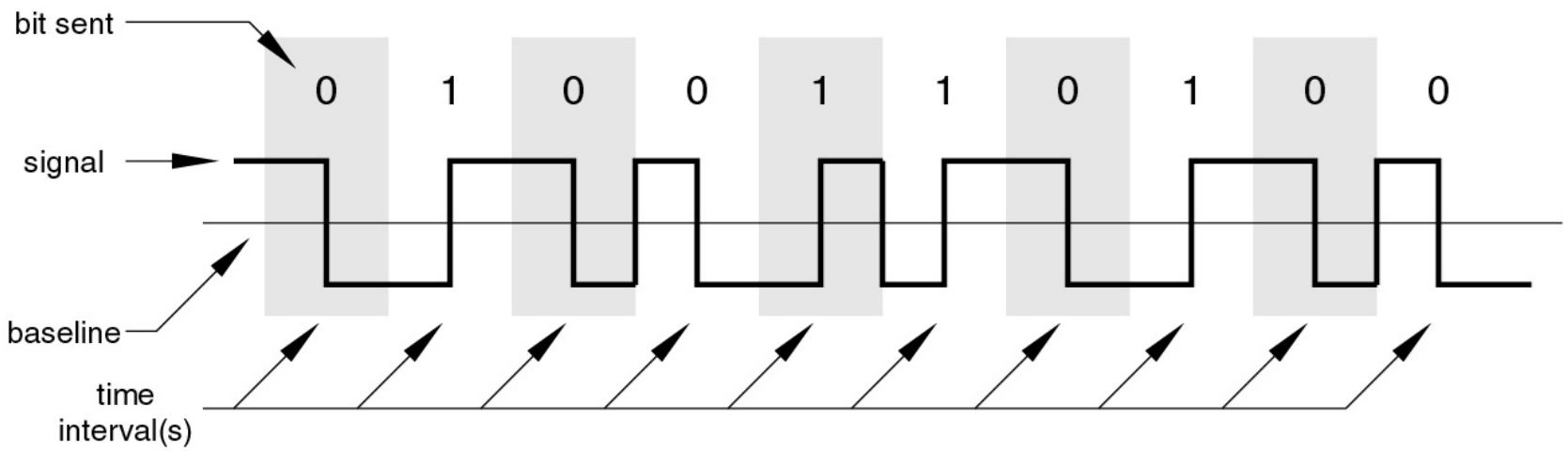
NRZ



Manchester Encoding

- Transition in middle of each bit period
- Transition serves as clock and data
- **Low to high represents one**
- **High to low represents zero**
- Used by IEEE 802.3 (Ethernet)

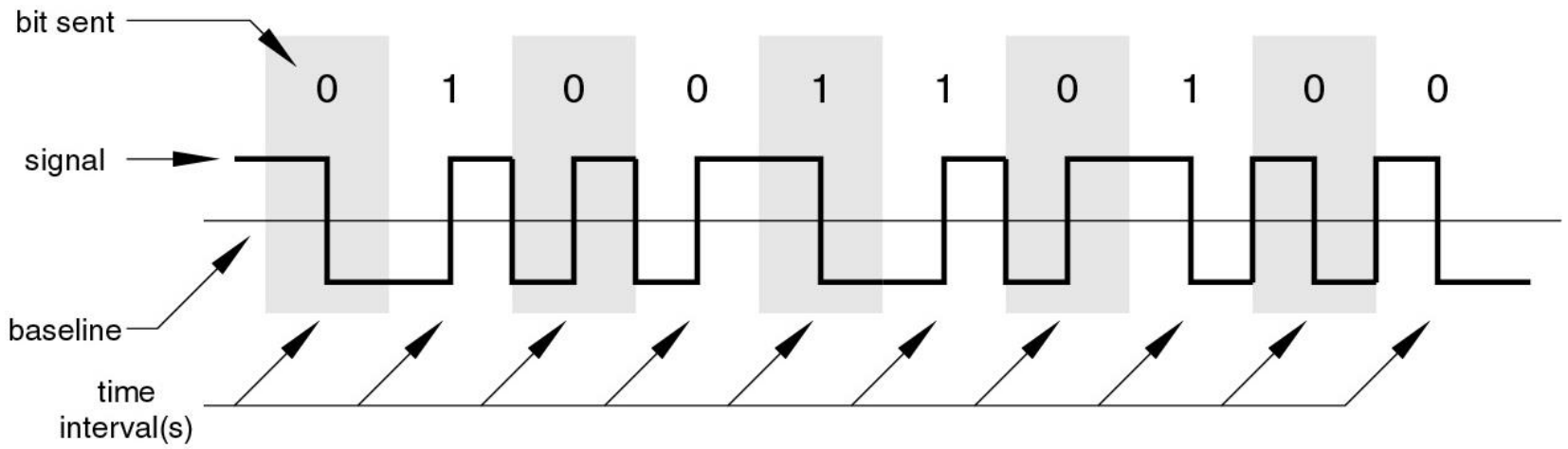
Manchester Encoding



Differential Manchester Encoding

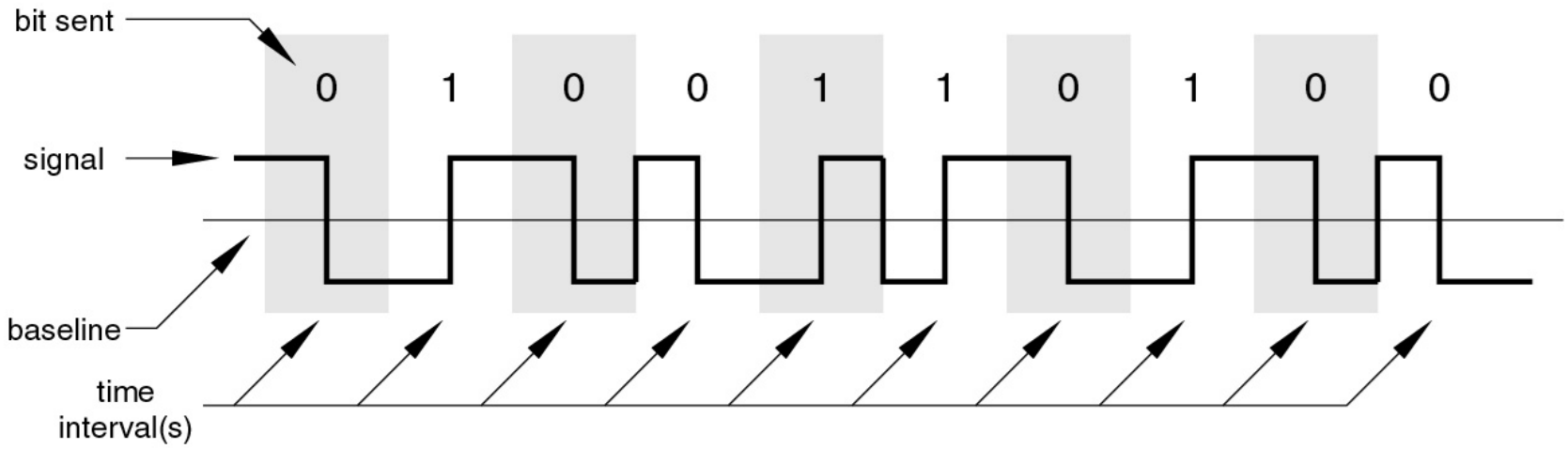
- **Transition** at start of bit period represent 0
- **No transition** at start of bit period represent 1
- Used by IEEE 802.5

Differential Manchester Encoding

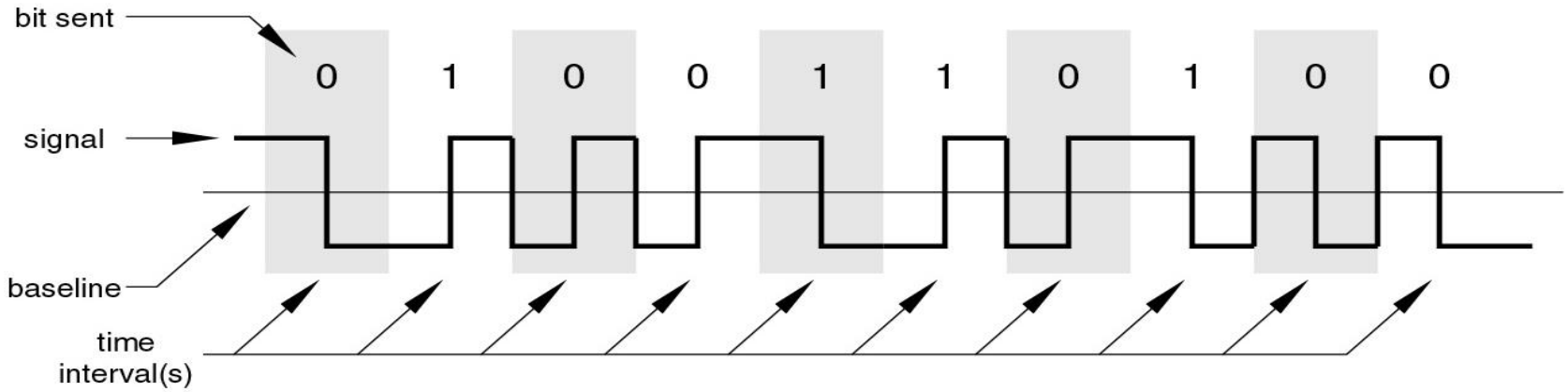


Manchester Encoding

Manchester Encoding



Differential Manchester Encoding



Digital Data - Analog Signal

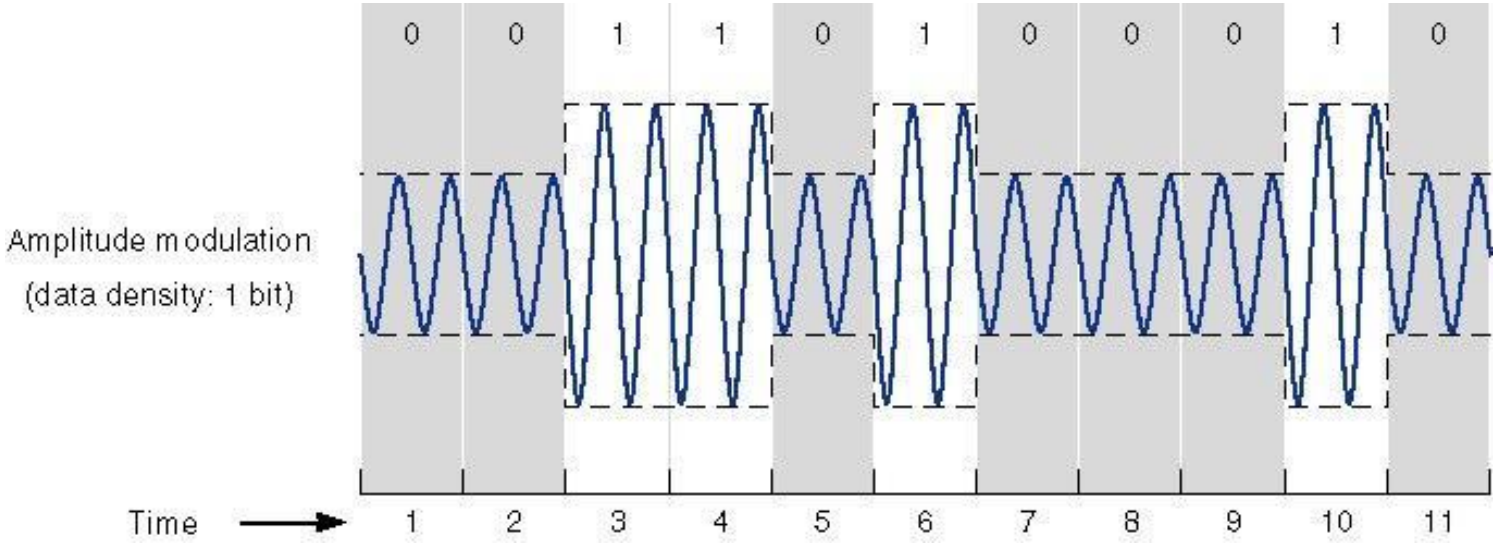
Digital Data, Analog Signal

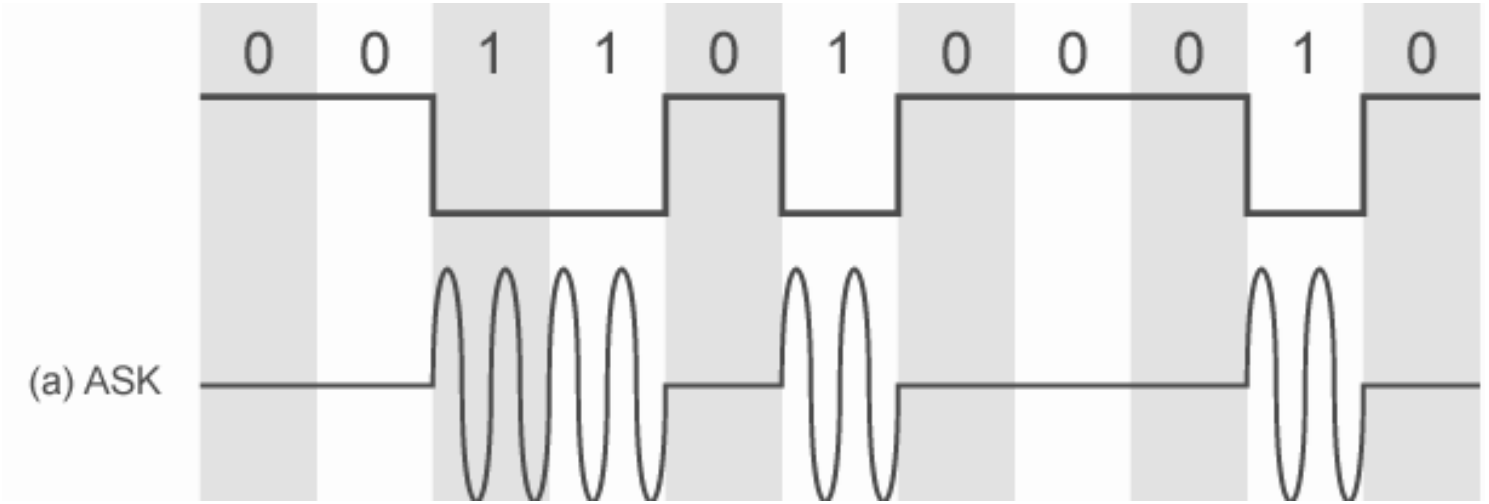
- We now consider the case of transmitting digital data using analog signals.
- In modulation, one characteristic of a carrier wave is changed based on the information signal that we wish to transmit (modulating signal).
- Characteristic of a signal could be the amplitude, phase, or frequency, which result in
  - Amplitude shift keying (ASK)
  - Frequency shift keying (FSK)
  - Phase shift keying (PSK)

Amplitude Shift Keying

- In ASK, the two binary values are represented by two different amplitudes of the carrier frequency.
- ASK is susceptible to sudden gain changes and is a rather inefficient modulation technique.
- Used in optical fiber, where one signal element is represented by a light pulse while the other signal element is represented by the absence of light.

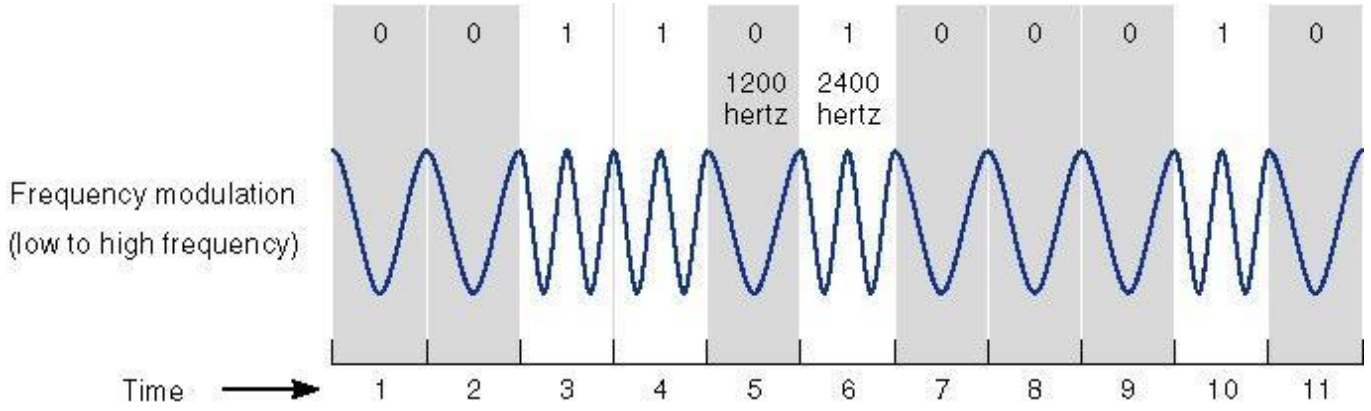
Amplitude Shift Keying





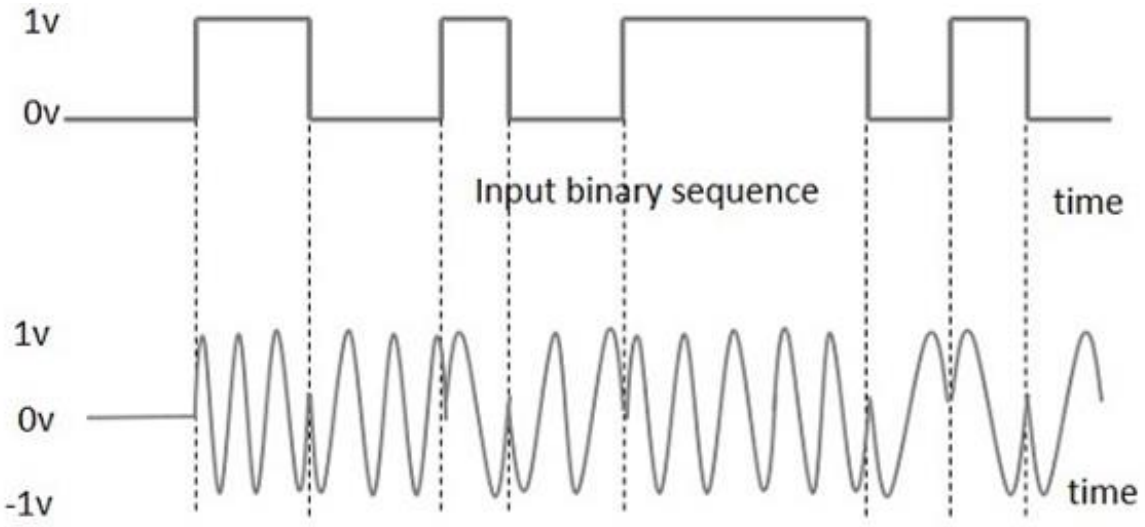
Binary Frequency Shift Keying

- Two binary values represented by two different frequencies
- 0 and 1 are represented by different frequencies
- Used for high-frequency (3 to 30 MHz) radio transmission



Phase Shift Keying

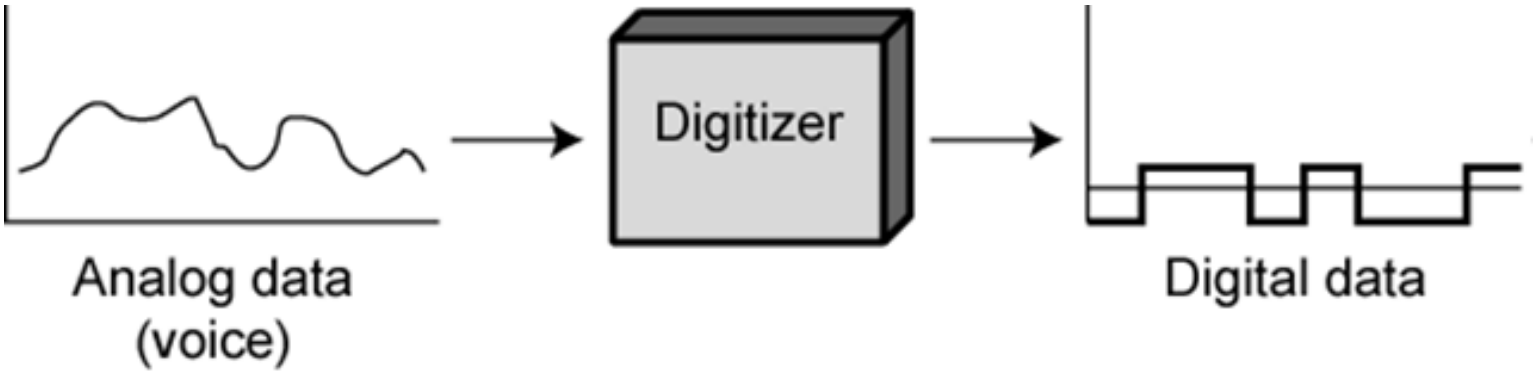
- Phase of carrier signal is shifted to represent data
- If the phase of the carrier wave does not change, then the signal state stays the same (0 or 1).
- If the phase of the wave changes by 180 degrees -- that is, if the phase reverses -- then the signal state changes (from 0 to 1, or from 1 to 0).



Analog Data - Digital Signal

Analog Data, Digital Signal

- Conversion of analog data into digital data
- Often digitized to be able to use digital transmission facilities.
- Digital data can then be transmitted using NRZ-L or other encoding

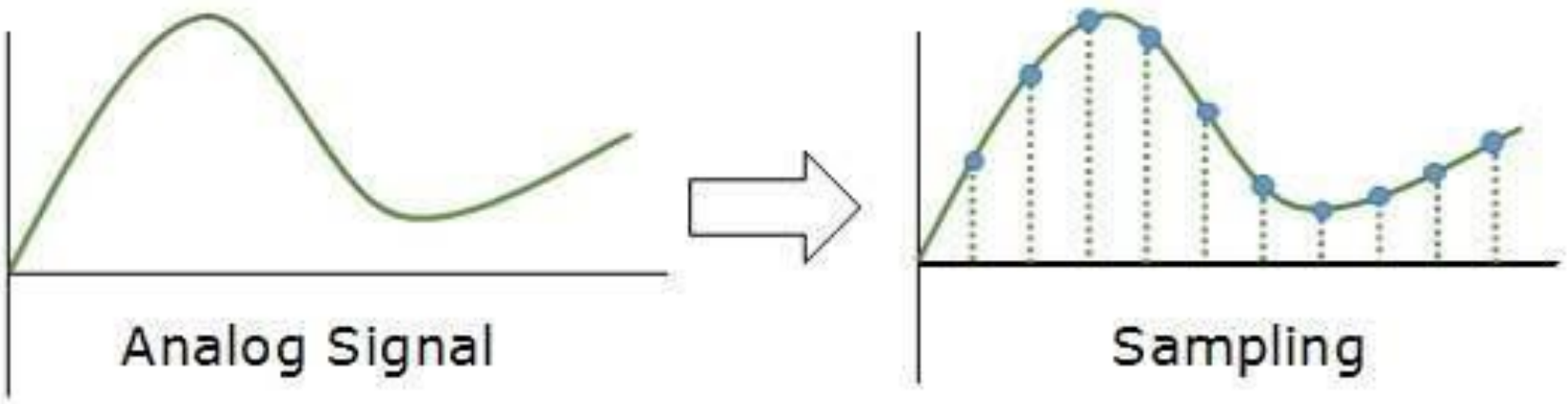


Pulse Code Modulation (PCM)

- To convert analog wave into digital data, one encoding scheme is **Pulse Code Modulation** (PCM).
- PCM is one of the most commonly used method to convert analog data into digital form. It involves three steps:
  - Sampling
  - Quantization
  - Encoding

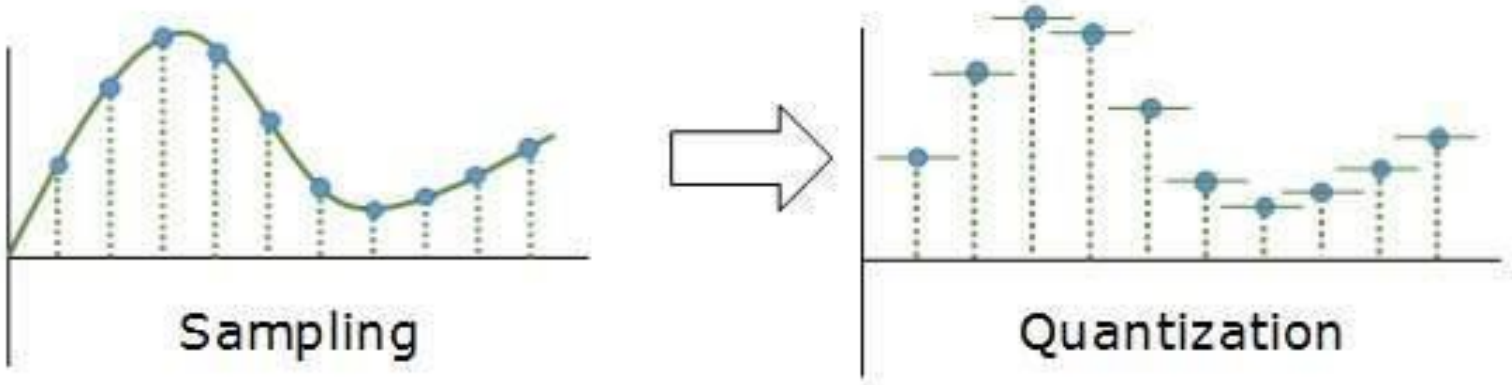
PCM - Sampling

- The analog signal is sampled periodically every T interval.
- According to Nyquist Theorem, the sampling rate must be at least two times of the highest frequency of the signal.
- Voice data limited to below 4000Hz, so it will require 8000 sample per second



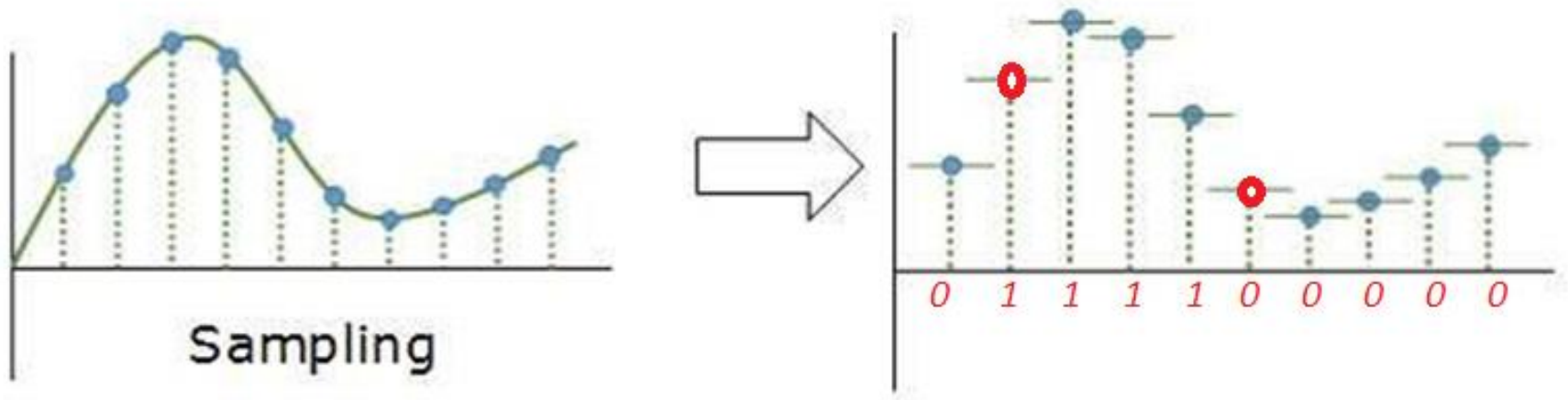
PCM - Quantization

- Sampling yields discrete values of continuous analog signal.
- Every discrete value shows the amplitude of the analog signal at that instance.
- Quantization is the process of defining the number of levels between the maximum amplitude value and the minimum amplitude value.

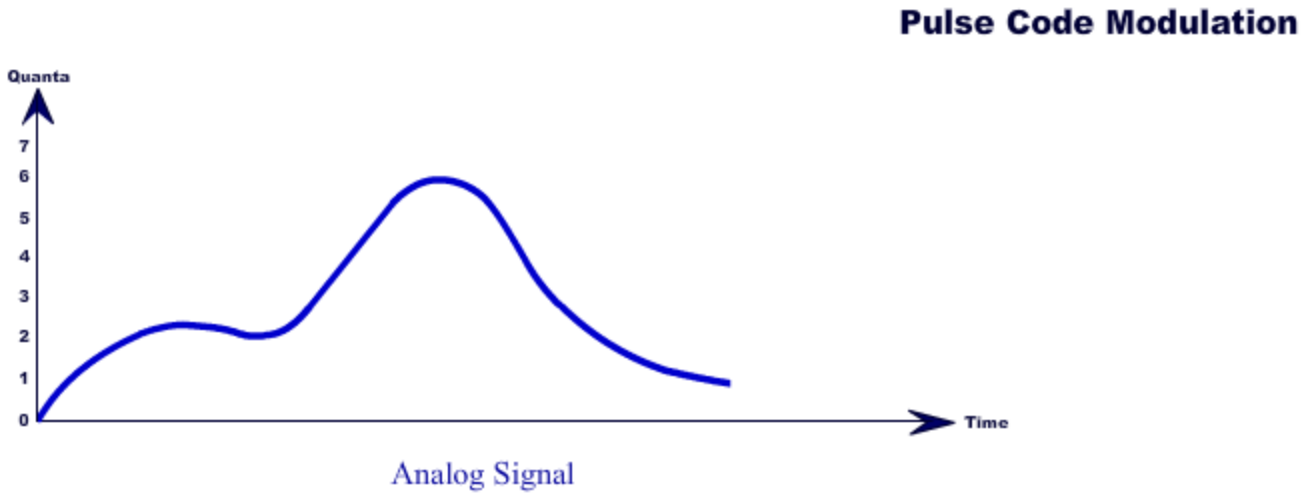


PCM - Encoding

- Now we need to assign each level a digital value.
- If we have 16 level, we need to assign 4 bit to each level. 2 level 1 bit, 4 levels 2 bits etc.
- The more the sampling rate and number of levels, the better the quality of conversion.



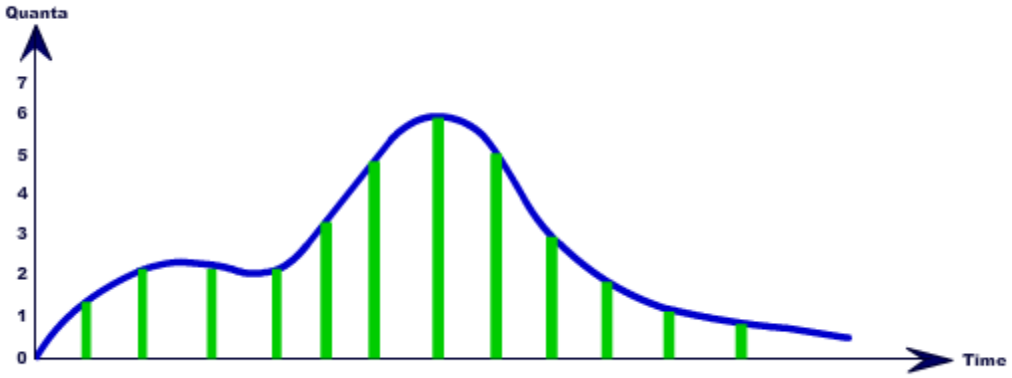
PCM Example



PCM Example

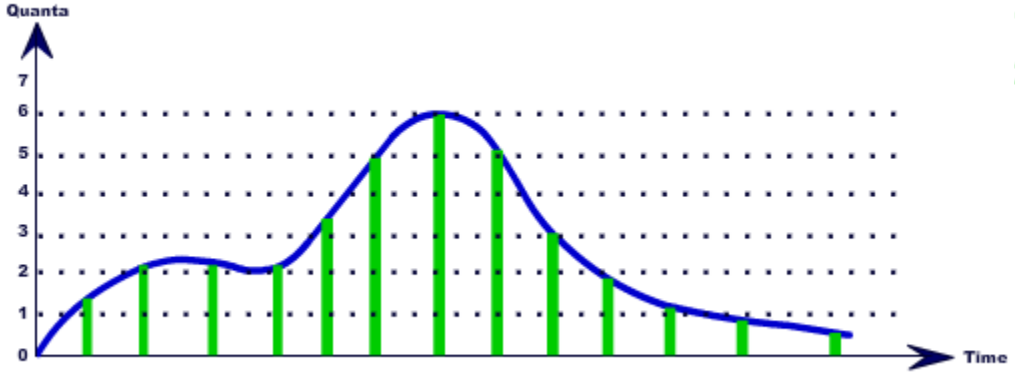
Pulse Code Modulation

1. Sampling



Analog Signal

PCM Example

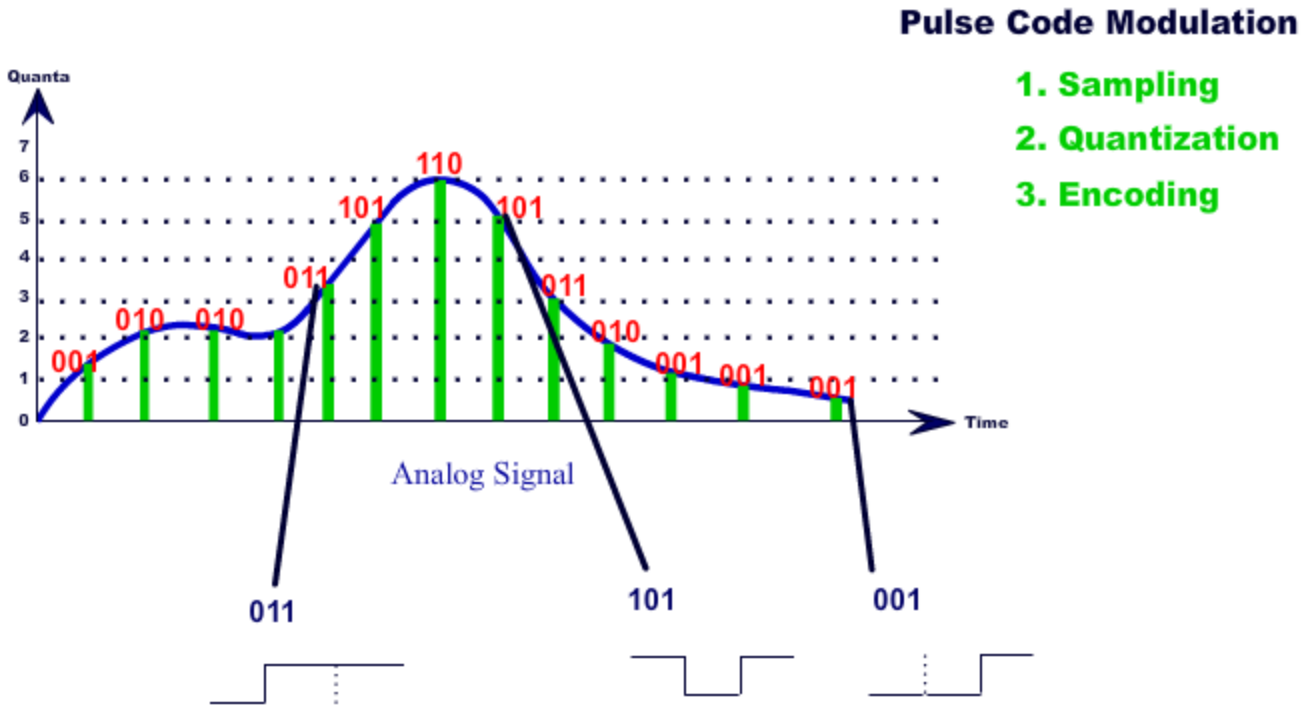


Analog Signal

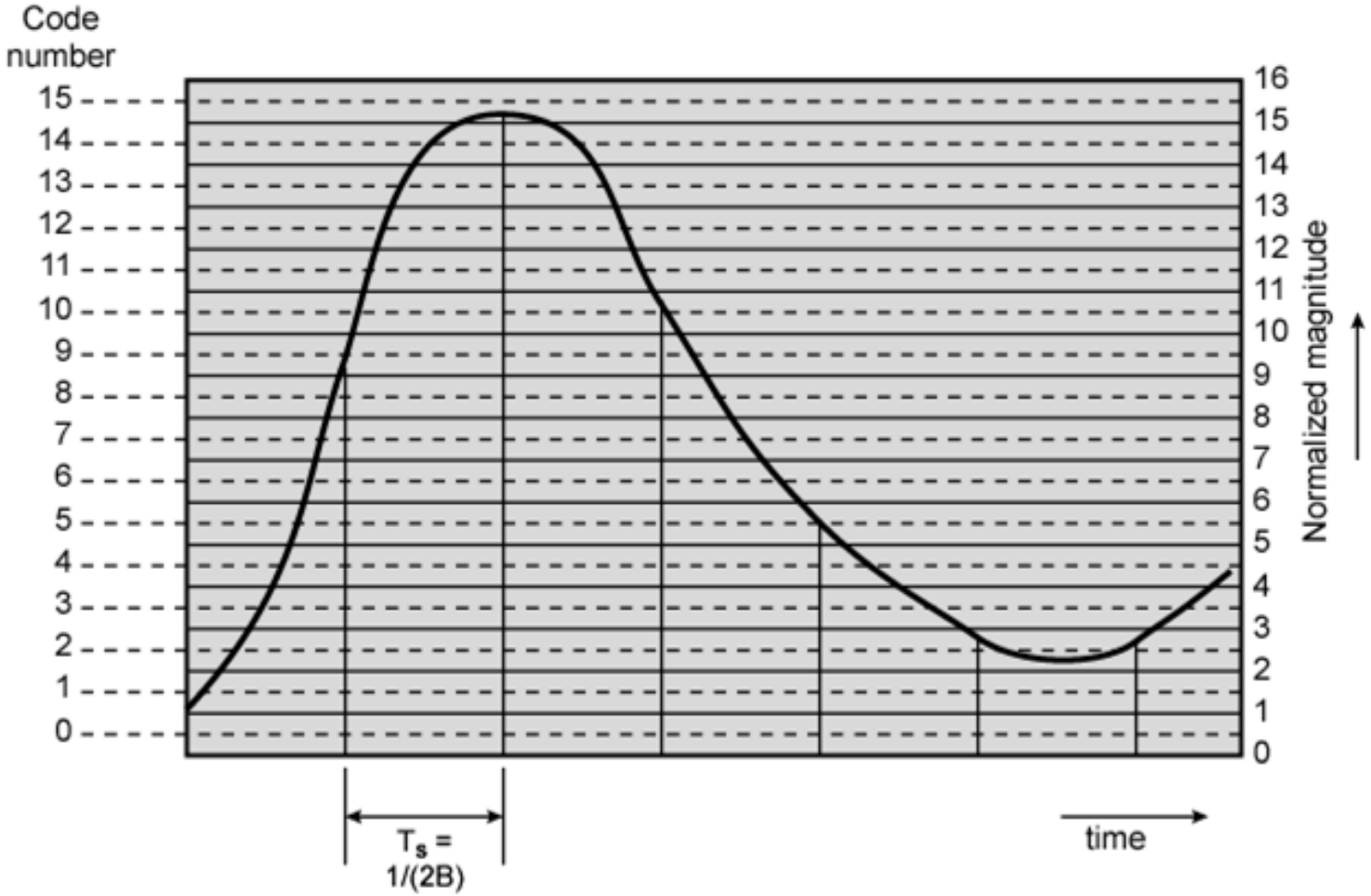
Pulse Code Modulation

1. Sampling
2. Quantization

PCM Example

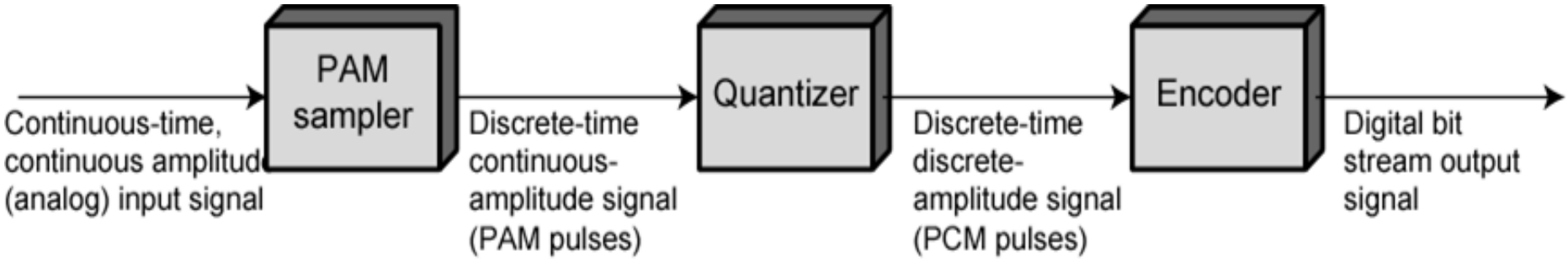

Pulse Code Modulation
1. Sampling
2. Quantization
3. Encoding
Quanta
7
6
5
4
3
2
1
0
001
010
010
011
101
110
101
011
010
001
001
001
Time
Analog Signal
011
101
001

PCM Example



PAM value	1.1	9.2	15.2	10.8	5.6	2.8	2.7
quantized code number	1	9	15	10	5	2	2
PCM code	0001	1001	1111	1010	0101	0010	0010

PCM Block Diagram



Analog Data - Analog Signal

Analog Data, Analog Signals

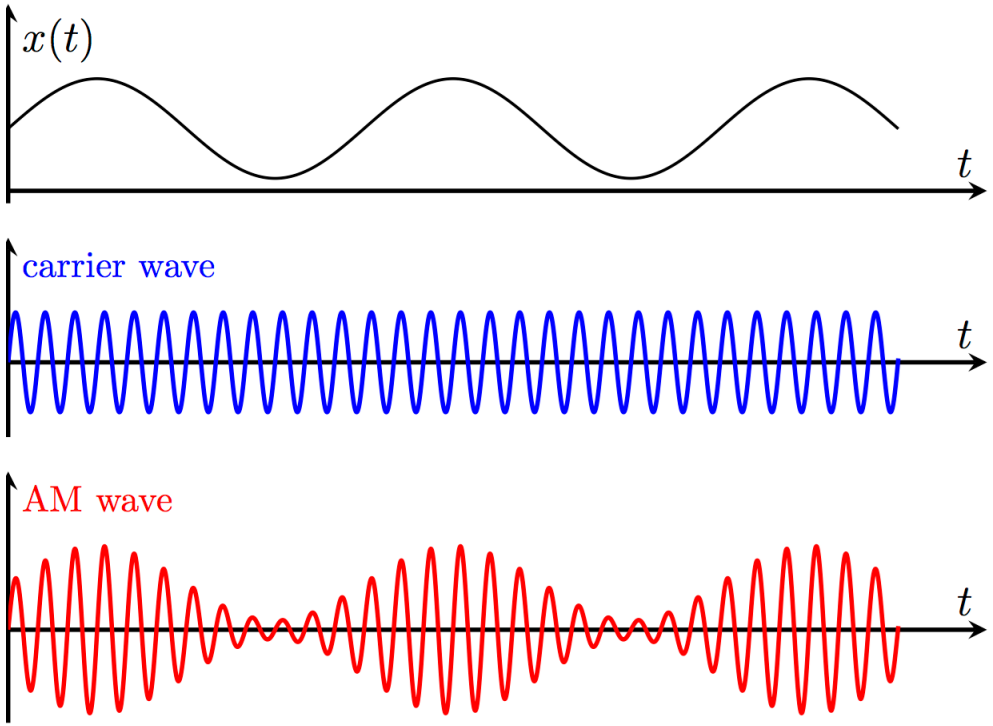
- Analog data can be modulated by a carrier frequency to produce an analog signal in a different frequency band, which can be utilized on an analog transmission system.
- Types of modulation
  - —Amplitude
  - —Frequency
  - —Phase

Modulation: Why?

- The original signals are commonly referred to as baseband signals.
- The process of shifting the baseband signal to passband range is called Modulation while the reverse is called Demodulation.
- Reasons for modulation:
  - Modulation allows us to send a signal over a higher frequency range. If every signal gets its own frequency range, then we can transmit multiple signals simultaneously over a single channel, all using different frequency ranges.
  - Another reason to modulate a signal is to allow the use of a smaller antenna.

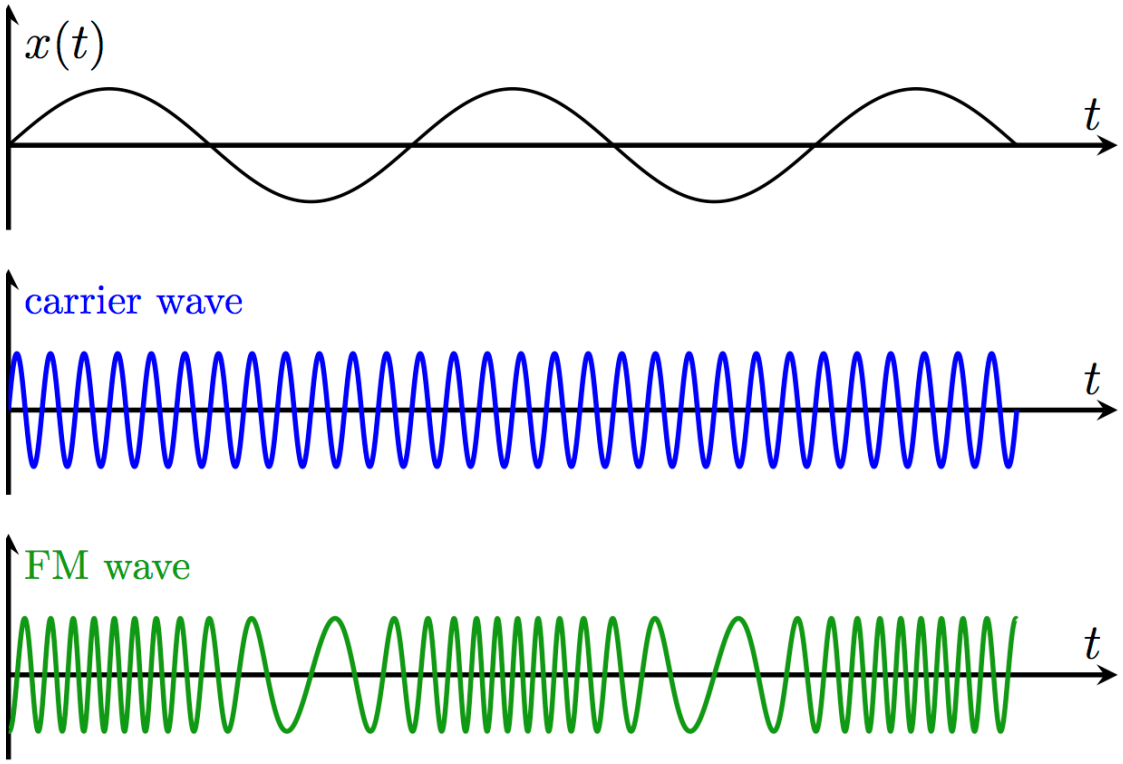
Amplitude Modulation

- In amplitude modulation, the amplitude (signal strength) of the carrier wave is varied in proportion to that of the message signal being transmitted.



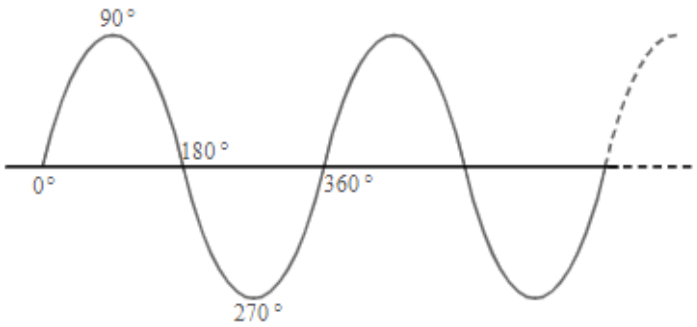
Frequency Modulation

- Frequency modulation is the encoding of information in a carrier wave by varying the frequency of the carrier wave.

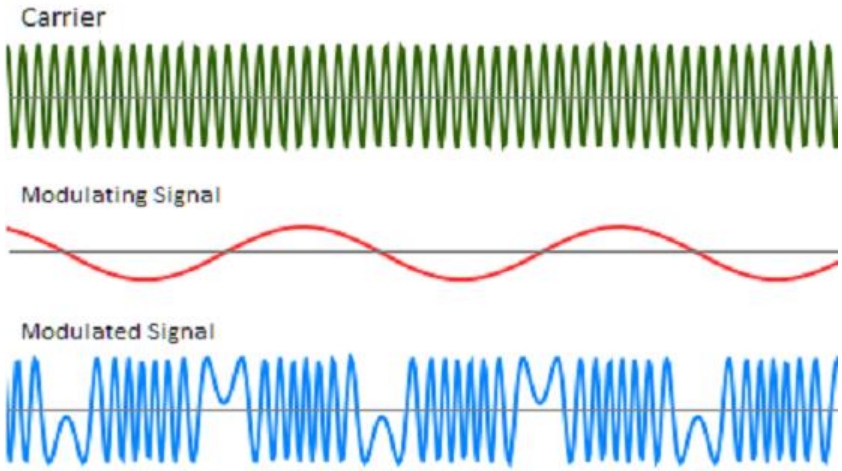


Phase Modulation

- Phase modulation (PM) is a method in which the phase of the carrier wave is varied according to input message.



A Sine Wave



Phase Modulation

Bits Rate Versus Baud Rate Versus Symbol Rate

- Bit rate is simply the number of bits (i.e., 0's and 1's) transmitted in per unit time.
- While Baud rate or symbol rate is the number of signal units/ symbols transmitted per unit time that is needed to represent those bits.
- A bit is a unit of information, a baud is a unit of signaling speed, the number of times a signal on a communications circuit changes.
- The bit rate and the symbol rate (or baud rate) are the same only when one bit is sent on each symbol